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Diurnal Variation in Swim Performance Remains, Irrespective of Training Once or Twice Daily

Louise Martin, Alan M. Nevill, and Kevin G. Thompson

Purpose: Fast swim times in morning rounds are essential to ensure qualification in evening finals. A significant time-of-day effect in swimming performance has consistently been observed, although physical activity early in the day has been postulated to reduce this effect. The aim of this study was to compare intradaily variation in race-pace performance of swimmers routinely undertaking morning and evening training (MEG) with those routinely undertaking evening training only (EOG). **Methods:** Each group consisted of 8 swimmers (mean \pm SD: age = 15.2 ± 1.0 and 15.4 ± 1.4 y, 200-m freestyle time 132.8 ± 8.4 and 136.3 ± 9.1 s) who completed morning and evening trials in a randomized order with 48 h in between on 2 separate occasions. Oral temperature, heart rate, and blood lactate were assessed at rest, after a warm-up, after a 150-m race-pace swim, and after a 100-m time trial. Stroke rate, stroke count, and time were recorded for each length of the 150-m and 100-m swims. **Results:** Both training groups recorded significantly slower morning 100-m performances (MEG = +1.7 s, EOG = +1.4 s; $P < .05$) along with persistently lower morning temperatures that on average were -0.47°C and -0.60°C , respectively ($P < .05$). No differences were found in blood-lactate, heart-rate, and stroke-count responses ($P > .05$). All results were found to be reproducible ($P > .05$). **Conclusions:** The long-term use of morning training does not appear to significantly reduce intradaily variation in race-pace swimming or body temperature.

Key Words: adolescent, exercise performance, time of day, oral temperature

Qualification for finals requires swimmers to swim close to their personal bests during morning heats, so the ability to swim fast in the morning is critical to successful swimming. Significant intradaily variation has been consistently reported for maximal swimming performance and is typically attributed to diurnal variation of critical physiological^{1,2} and psychological variables.¹ Maximal swimming performance has been observed to occur during late afternoon/early

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evening, coinciding with the time course of daily peak in the body-temperature rhythm.³ Arnett⁴ reported a significant reduction in intradaily variation in 100-m freestyle performance after the inclusion of morning training sessions for 16 weeks. Although a significant variation in oral temperature was still evident and to be expected, the reported increase in mean morning temperature from $34.7 \pm 0.5^{\circ}\text{C}$ to $35.8 \pm 0.4^{\circ}\text{C}$ after morning training is questionable, indicating some degree of measurement error or the influence of external factors that might not have been adequately controlled.

Enhanced morning performance might occur as a result of either a change in physiological rhythms induced by routinely waking up and being physically active early in the day, as postulated by Reilly⁵ and recently demonstrated by Edwards et al.,⁶ or a time-of-day effect on responses to training that can be observed through enhanced performance at the specific time of day when training is undertaken.^{7,8} Regular morning training might, therefore, be beneficial in reducing the disparity between morning and evening maximal swimming performances as a result of enhanced adaptations to morning exercise. The purpose of this study was to compare the intradaily variation in race pace of swimmers undertaking morning and evening training (MEG) and swimmers undertaking evening training only (EOG).

Methods

Subjects

Sixteen competitive age-group swimmers volunteered to participate in the investigation (Table 1). The morning and evening group (MEG) comprised 8 swimmers who routinely trained both in the morning (6:30–7:30 AM) and evening (4:00–6:00 PM), 5 days a week. The evening-only group (EOG) consisted of 8 swimmers who routinely trained in the evening 5 days a week (7:00–10:00 PM). All swimmers completed the Horne and Ostberg⁹ morningness–eveningness questionnaire. The MEG swimmers were classed as “neither,” and the EOG swimmers were classed as “moderate evening type.” Before participation in the study, parental consent and child assent were obtained, and all procedures gained ethical approval by the relevant institutional ethics committee.

Design

A repeated-measures randomized trial was undertaken to establish physiological, kinematic, and performance variables during morning and evening swimming. Independent groups from 2 separate swimming clubs were used to provide a

Table 1 Participant Characteristics for Morning-and-Evening (MEG) and Evening-Only (EOG) Training Groups, Mean \pm SD*

Group	n	Age (y)	Height (m)	Mass (kg)	200-m freestyle time (s)
MEG	8	15.2 ± 1.0	1.68 ± 0.05	59.8 ± 5.4	132.8 ± 8.4
EOG	8	15.4 ± 1.4	1.73 ± 0.08	61.9 ± 8.6	136.3 ± 9.1

*No significant differences between MEG and EOG for all variables ($P > .05$).

comparison of the different training regimens. Age, gender, and performance ability were matched as closely as possible, and there were no statistically significant differences between the 2 training groups. Trials were repeated on 2 separate occasions within 7 days of each other to ensure reliability of the data.

Methods

Each swimmer undertook a morning and evening trial in random order with 48 hours in between. Both trials were then repeated within 7 days. Time of day for morning trials was similar (MEG = 6:30–7:30 AM, EOG = 7:00–9:00 AM) but for the evening trials was dictated by the habitual training routines of the 2 groups and could therefore not be exactly matched (MEG = 4:30–6:30 PM, EOG = 8:00–10:00 PM). This served to optimize any impact of temporal specificity of training while enabling trials to occur as closely as possible to the commonly reported windows for peak and trough values of critical physiological variables, particularly temperature.^{1,3,10}

Participants were told to refrain from physical activity, food consumption, or ingestion of caffeinated beverages for 3 hours before testing. Water consumption was unrestricted during this time. After 10 minutes of seated rest, oral temperature and heart rate (S610, Polar, Finland) were recorded. Oral temperature was measured by placing a digital thermometer (Omron, UK) sublingually for 3 minutes as previously described.² Heart rate was recorded continuously (S610, Polar, Finland) and was reported as the mean value of the final minute of rest. A single lysed microtube (Analox Instruments, London, UK) of capillary blood was taken from each participant's earlobe. Each sample was mixed thoroughly, capped, and frozen for subsequent analysis in the laboratory for lactate concentration (LM5, Analox Instruments, London, UK).

Swim speeds for the warm-up and the 150-m race-pace swim were determined from each swimmer's current 200-m freestyle time. The 400-m warm-up was completed at a pace equivalent to 70% of each swimmer's 200-m race pace and at an even pace. Swim time was controlled throughout using an Aquapacer unit (Challenge and Response, Inverurie, Scotland). The Aquapacer was programmed to emit a beep at designated time intervals, equivalent to the end of each length, to ensure that the swimmer produced an evenly paced swim. Participants were instructed to "turn on the beep by ensuring that their feet touched the wall on the beep." On completion of the warm-up, heart rate and rating of perceived exertion (Borg scale) were recorded. Participants then rested for 5 minutes, during which time oral temperature and capillary blood lactate were assessed as before. Participants then completed the 150-m swim at 200-m race pace. A 150-m swim was used to enable participants to perform at a constant race pace without fatigue, so any inability to maintain race pace could be associated with time-of-day effects. During the 150-m at race pace, stroke rate (Base 3 function, Timestar), stroke count, and time (Sport-line, UK) were recorded for each pool length. On completion, heart rate, rating of perceived exertion, oral temperature, and capillary-blood lactate were measured. After 5 minutes of passive rest the participants completed a maximal-effort 100-m freestyle time trial from a push-off, during and after which the same kinematic and physiological variables were measured as after the 150-m swim.

Statistical Analysis

For each variable the mean of the 2 trials was used in the analysis because dependent t tests indicated there was no significant difference between the 2 trials for either group ($P > .05$). A 2-way ANOVA with repeated measures (2 times of day \times 2 training groups) was performed on all data to identify significant time-of-day effects within each group and between the MEG and EOG groups. In addition, dependent t tests were used to indicate time-of-day differences in the 150-m race pace and 100-m time trial for each training group. It should be noted that because these comparisons were all planned, no adjustments for multiple comparisons, such as Bonferroni, were required. Statistical significance was set at $P \leq .05$ throughout, and all analyses were undertaken using SPSS v 8.0.

Results

Time-of-Day Effects

Oral temperature was significantly lower during morning trials for both training groups at rest ($F_{1,14} = 42.913$, $P = .001$), post-warm-up ($F_{1,14} = 20.935$, $P = .003$), and after the 100-m time trial ($F_{1,14} = 19.760$, $P = .003$; Table 2). Despite the use of a pacing device, 150-m swim time was faster during evening trials for both training groups. This was only significant, however, in the MEG ($F_{1,14} = 18.394$, $P = .001$, or $t = 3.533$, $P = .02$; Table 3). Maximal swimming performance was significantly slower during morning trials for both training groups (MEG: $t = 6.279$, $P = .001$; EOG: $t = 4.435$, $P = .003$). The level of intradaily variation for 100-m swim time was higher for the MEG (2.5%) than for the EOG (2.0%). Heart rate, blood lactate, and rating of perceived exertion were similar throughout in morning and evening trials ($P > .05$; Table 4).

Training-Group Effects

With the exception of the 150-m swim time, the responses of the 2 training groups were similar for all the physiological and performance assessments. This suggests that the time of day at which training was routinely undertaken had minimal effect on intradaily variation. Results of the kinematic data were also very similar for the 2 training groups, although there was a significant interaction between time of day and training group for stroke rate during both the 150-m swim ($F_{1,14} = 3.163$, $P = .012$) and the 100-m time-trial swim ($F_{1,14} = 6.172$, $P = .026$). Examination of the data reveals that the MEG used a higher stroke rate during evening trials than during the morning trials, whereas the EOG used similar stroke rates at both times of day (Figure 1).

Discussion

The purpose of this study was to determine whether training once or twice daily affected the diurnal variation in swim performance. Table 3 shows that significant diurnal variation in swim performance was observed in both training groups. The

Table 2 Oral Temperatures for Both Training Groups, Mean ± SD

	Morning-and-Evening Group			Evening-Only Group		
	Morning trial	Evening trial	Difference	Morning trial	Evening trial	Difference
Rest	35.14 ± 0.50	35.80 ± 0.40	+0.66*	36.02 ± 0.50	36.75 ± 0.3	+0.73*
Post-warm-up	34.77 ± 0.77	35.43 ± 0.65	+0.66*	35.95 ± 0.30	36.43 ± 0.31	+0.48*
Post-150-m	35.16 ± 1.02	34.99 ± 1.49	-0.17	36.03 ± 0.27	36.67 ± 0.31	+0.64*
Post-100-m	34.85 ± 0.85	35.57 ± 0.85	+0.72*	36.29 ± 0.27	36.85 ± 0.21	+0.56*

*Significantly higher than morning trial ($P < .05$).

Table 3 Swimming Times (seconds) for Morning and Evening Trials for Both Training Groups, Mean ± SD

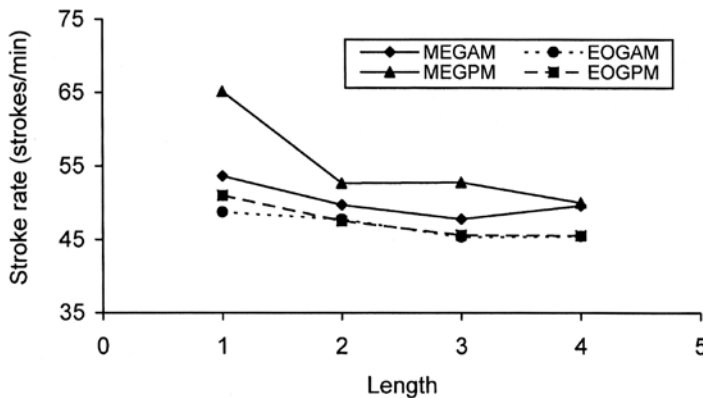
	Morning-and-Evening Group			Evening-Only Group		
	Morning trial	Evening trial	Difference	Morning trial	Evening trial	Difference
150-m race pace	101.9 ± 5.2	100.1 ± 5.4	-1.8	106.2 ± 8.5	104.7 ± 7.9	-1.5
100-m time trial	65.7 ± 3.8	64.0 ± 3.7	-1.7*	67.0 ± 6.0	65.6 ± 5.8	-1.4*

*Significantly faster than the morning trial ($P < .05$).

Table 4 Heart Rate (beats/min) and Blood Lactate (mmol/L) Levels for Both Training Groups, Mean \pm SD*

	Morning-and-Evening Group		Evening-Only Group	
	Morning trial	Evening trial	Morning trial	Evening trial
Rest				
heart rate	71 \pm 13	65 \pm 10	74 \pm 9	82 \pm 8
blood lactate	1.8 \pm 0.4	1.9 \pm 0.6	1.2 \pm 0.3	1.5 \pm 0.3
Post-warm-up				
heart rate	119 \pm 29	130 \pm 16	142 \pm 14	136 \pm 15
blood lactate	1.9 \pm 0.3	2.3 \pm 0.8	2.8 \pm 0.8	2.8 \pm 1.1
Post-150-m				
heart rate	163 \pm 19	159 \pm 19	172 \pm 9	177 \pm 6
blood lactate	6.6 \pm 0.6	7.1 \pm 1.0	6.2 \pm 1.5	7.0 \pm 1.5
Post-100-m				
heart rate	178 \pm 19	174 \pm 6	178 \pm 6	184 \pm 6
blood lactate	8.5 \pm 1.4	9.5 \pm 1.4	8.2 \pm 2.1	9.5 \pm 2.8

*No significant differences between groups for all variables ($P > .05$).

**Figure 1** — Stroke-rate pattern during 150-m swim for morning (AM) and evening (PM) trials for morning-and-evening (MEG) and evening-only (EOG) training groups.

EOG demonstrated significant intradaily variation in the maximal-effort 100-m time trial ($P < .05$), and the MEG demonstrated significant intradaily variation in the controlled 150-m race-pace swim and the maximal-effort 100-m time trial ($P < .05$). Indeed, the MEG demonstrated a higher percentage of intradaily variation than the EOG in both swims (150-m = 1.7% and 1.5%, 100-m = 2.5% and 2.0%,

respectively). This indicates that the diurnal variation in performance is maintained despite daily morning training. These findings are at variance with the research of Arnett,⁴ who reported that the intradaily variation in 100-m freestyle performance was no longer significant ($P > .05$) after the addition of morning training sessions for 16 weeks. The most likely explanation for these differences is related to the training status of the participants in the 2 studies. Arnett's initial data were collected after 4 weeks of afternoon-only training, which coincided with a phase of active recovery, and were compared with data collected after 4 months of full training. Such participants at the initial data-collection point are likely to have had a reduced training status with altered physiological, nutritional, and motivation levels, which are all thought to influence the time-of-day response¹¹ and thus make the participants more susceptible to diurnal variation in performance. In the present study, participants were used to evening-only training or morning and evening training and were therefore unaffected by short-term changes in training status. Furthermore, unlike the Arnett⁴ study, the present study used repeated trials; this suggests that the present data reflect a reproducible response to time-of-day effects.

Diurnal variation in maximal swimming performance has previously been linked to the circadian rhythm of body temperature.³ The findings of the present study provide further support for this premise, because oral temperature demonstrated a significant and persistent intradaily variation at rest, post-warm-up, post-150-m race-pace swim, and after the 100-m time trial in both training groups (Table 2). Persistence of the diurnal variation in temperature throughout the trial is in accord with previous studies monitoring temperature responses to warm-up^{11,13} and throughout a bout of exercise^{12,13} at different times of day. Arnett,⁴ however, reported a substantial elevation in morning oral temperature from $34.7 \pm 0.5^{\circ}\text{C}$ to $35.8 \pm 0.4^{\circ}\text{C}$ after the addition of morning training for 16 weeks. Based on this, it was anticipated that the MEG swimmers would demonstrate elevated morning temperatures in comparison with those of the EOG. This was not the case, however, because MEG oral temperature was typically 1.1°C lower than that of the EOG throughout the morning trials (Table 2).

This finding might be a reflection of the small, but unavoidable, difference in the timings of the morning trials for the 2 groups (MEG = 6:30–7:30 AM, EOG = 7:30–9:00 AM), because there is a rapid rise in body temperature in the hours immediately after waking. In addition, these large differences in oral temperature might reflect local effects in the mouth at the time of assessment, which is a limitation of this technique. Every care was taken, however, to ensure that the thermometer was located under the tongue with the mouth closed for a full 3 minutes before temperature being recorded—a technique that the authors have previously reported as highly reproducible in a similar population.¹⁴ Rectal temperature, a more robust marker of human circadian rhythms, was considered impractical in this design because of the pool environment, the repeated assessments in each trial, and the invasive nature of the measure in these young participants. Consequently, despite the potential limitations of using oral temperature, it provided the most practical assessment for this investigation.

Simple kinematic data of stroke rate and stroke count were also recorded during this investigation to determine whether there were observable differences in how the 2 training groups swam. Results indicate that both stroke rate and stroke count

varied length by length as expected, but there was no significant intradaily variation for either of these variables ($P > .05$), which is in agreement with previous research.¹⁴ There was, however, a significant interaction between time of day and training group for stroke rate during the 100-m time trial as a result of the MEG's using a higher stroke rate during the evening trial than the morning trial, whereas the EOG used a similar stroke rate for both trials (Figure 1). The data are inconclusive in suggesting that differences in stroke mechanics with time of day are a direct result of temporal specificity of training, possibly because of the insensitivity of these measures. The authors have previously reported a coefficient of variation of 1.8% for measurement of stroke rate using the same technique.¹⁴ Thompson et al.,¹⁵ however, recently showed that changes in stroke rate and stroke length are extremely subtle when small improvements in performance occur and are unlikely to be detected by hand timing (stroke rate) or stroke counting. Nevertheless, the observed significant difference in stroke rate in length 1 (Figure 1) might account, at least in part, for the larger percentage change observed in 100-m trial times between the MEG and EOG (2.5% vs 2.0%). Future research could consider the temporal effects on mechanisms of force production and stroke mechanics.

The 2 groups used in the present study were from 2 separate swimming clubs of a similar standard but with very different training regimens. As such, they provided an opportunity to observe these effects on intradaily variation of race-pace swimming. The applied approach to the investigation does require accepting some inherent limitations relating to an inability to control training volume and intensity before and during the investigation between the 2 clubs. Nevertheless, both groups were in a state of full training. Repeated trials were undertaken to ensure that the data were reliable, which has not been demonstrated in previous research that only report single trials.^{4,6}

Conclusion

Data from the present study indicate that the use of combined morning and evening training does not reduce intradaily variation in race-pace/maximal swimming or oral temperature. Training times are likely to be influenced by a range of factors outside a coach's control. This study would suggest that, even if the coach can run morning and evening training sessions, performance variation depends on the time of day. The non-steady-state exercise bouts showed that time-of-day effects were not observed in key physiological data, for example, heart rate and blood lactate. It appears, however, that performance variation is linked to either the persistent daily variation in body temperature or a stroke-kinematics limitation, although these might not be causal.

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